# Do exercises for patellofemoral pain reflect common injury mechanisms? A systematic review



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**ABSTRACT**

**Objectives**: Current best evidence has reported that therapeutic exercise programs that are designed to treat patellofemoral pain (PFP) should include both hip and knee specific exercises. The purpose of this review was to 1) examine the quality/comprehensiveness of exercise reporting in this field; 2) quantify the extent to which individual exercises comprised task-specific elements (single limb stance; eccentric control of the hip; rotational z-axis control) most likely to address key pathomechanics associated with PFP.

**Design:** Systematic review: a systematic survey of RCTs

**Methods**: PubMed, CINAHL, Medline, Physiotherapy Evidence Database (PEDro) and SPORT Discus databases were searched for randomized controlled trials that addressed PFP utilizing a proximal control hip focused rehabilitation paradigm. The therapeutic exercise programs were evaluated, and each individual exercise was extracted for analysis. Quality assessments included the PEDro Scale and the Consensus on Exercise Reporting Template (CERT) was utilized to score the reporting of the interventions.

**Results**: 19 studies were included in the final analysis. 178 total exercises were extracted from the proximal hip and knee rehabilitation programs. The exercises were analyzed for the inclusion of elements that align with reported underlying biomechanical mechanisms.

**Conclusions**: The vast majority of the exercises were sagittal plane, concentric, non-weight bearing exercises, whereas multiplanar exercises, single limb weightbearing, and exercises where loading was directed around the longitudinal z-axis, were considerably under-represented. Current exercises for PFP utilize simplistic frameworks that lack progression into more task specific exercise, and are not reflective of the complex injury etiology.

**Keywords:** Exercise, Hip, Knee, Patellofemoral Pain, Proximal Muscle Rehabilitation, Sports

## 1. Introduction

Patellofemoral Pain (PFP) is a common condition affecting individuals of all ages and activity levels.[1-3] The prevalence of PFP varies by population but may be as high as 20-25% in active populations.[2,4] This condition affects females more than males, and almost two thirds of runners with PFP are female.[5]

Exercise is a central component of PFP management.[6-8] Initial interventions were limited to local strengthening of the knee,[3,9] but have since progressed to incorporate ‘proximal exercises’ targeting the hip and pelvis.[2] Whilst randomized clinical trials (RCTs) show that proximal rehabilitation often results in short term improvement to pain and function,[10-13] the long-term prognosis of PFP remains poor.[14] Over 50% of patients with PFP have unfavorable recovery at 5-8 year follow ups,[15] with others reporting that 90% of patients have residual pain and dysfunction four years post-diagnosis.[16] The effect of exercise rehabilitation on PFP patient’s quality of life (QOL) is also unclear and may be comparable to control interventions.[15,17]

PFP etiology is complex[18-20] but a primary factor associated with its poor long-term prognosis, is the lack of consensus on an optimal exercise regimen.[21] Many clinicians favor proximal exercises, but the clinical interpretation of ‘proximal’ varies considerably, from simple hip-focused strengthening exercises, to more generalized dynamic warm-up activities.[21] There is a concern that either extreme is suboptimal, as they cannot fully address key pathomechanics associated with PFP,[19,22,23] such as excessive or uncontrolled internal rotation of the femur (in relation to the patella), particularly under high load and/or single limb conditions [Fig. 1].[2,20,24]

Optimal rehabilitation requires a task specific approach, whereby exercises are progressed via specificity and optimal loading principles.[25] This would include addressing the muscular deficits affecting individuals with PFP, such as isometric, concentric and eccentric strengthening of the hip and knee musculature.[26] Also, specific neuromuscular control exercises to enhance the rate of muscular force development,[26] and isometric force steadiness focused training.[27] It is therefore pragmatic that PFP rehabilitation eventually exposes patients to conditions involving: single limb loading, eccentric hip strengthening, external perturbations around multiple planes, particularly about the z-axis.[21] Although nearly 100 reviews on PFP management have been published none have considered the individual content and design of each rehabilitation exercise.[6] A recent study stated that exercise prescriptions in RCTs for PFP are poorly reported, and the authors suggested adding the Consensus on Exercise Reporting Template (CERT) in future reviews.[28] The aim of this systematic review is to include the CERT tool, in order to assess the exercise content employed within randomized controlled trials (RCTs) implementing a proximal approach to the treatment of PFP. Our key objectives were to:

1). examine the quality/comprehensiveness of exercise reporting in this field

2). quantify the extent to which individual exercises incorporate complex, task-specific elements (single limb stance; eccentric control of the hip; rotational z-axis control) relevant to key pathomechanics associated with PFP.

## 2. Methods

A systematic literature review was conducted after consulting the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement and the checklist completed.[29] The review was registered at PROSPERO (CRD42017076115). Since the time of registration several deviations from the original submission to PROSPERO occurred. A systematic literature search of the PubMed, CINAHL, Medline, Physiotherapy Evidence Database (PEDro) and SPORTDiscus databases was performed in March 2020 to obtain relevant studies for the review. The date ranges utilized for the review were from database inception to the date the search was conducted. The search strategy included filters to only include publications in the English language and including only human participants. In addition, the study archives of the authors were manually searched, and the reference lists of retrieved articles were hand searched for possible information on trials of interest. Search terms included keywords or utilized Medical Subject Headings (MeSH) where appropriate: “hip”, “knee”, “joint” combined with the terms “patellofemoral”, “patella”, “strength*”. Google scholar was also searched using a combination of the aforementioned key words. The PRISMA flow document detailing the search can be found as an online Supplementary File 1.

The inclusion criteria was as follows; the authors: 1) clearly stated that the therapeutic exercises that were being prescribed were specific to the hip and/or surrounding lumbopelvic musculature; 2) studies with male or female participants who were diagnosed with patellofemoral pain syndrome or anterior knee pain were included in this review; 3) Only randomized and/or controlled trials (RCTs) utilizing proximal hip muscle exercises in combination with or without knee exercises were included. Considering many hip focused exercises load the quadriceps simultaneously (e.g. single leg squats, step ups)[30] the hip and knee exercises were analyzed together in this review. Feasibility studies or protocol papers, post-surgical rehabilitation, editorial letters, case reports, commentaries, abstracts without full text and articles without a description of the exercises, and the authors could not be reached to identify the exercises utilized were ultimately excluded.

The identification of relevant articles, titles and abstracts were downloaded into EndNote X8.2 (Thomson Reuters, USA), where duplicates were removed. To identify relevant articles, titles and abstracts of all the captured citations were independently screened by at least two authors (SLD, DTT, AAW) applying the *a priori* inclusion criteria. Full text articles were then retrieved if the abstract provided insufficient information to determine eligibility for inclusion. In the case of differing assessments of the retrieved studies between the reviewing authors, the specific study was collaboratively discussed amongst the three authors. All criteria were again independently applied by two authors (SLD, AAW) to the full-text of the articles that passed the initial screening process. If a consensus could not be reached on the decision for final inclusion, a fourth author (CMB) was consulted.

Physiotherapy Evidence Database (PEDro) Scale

Two reviewers (SLD, DTT) independently assessed the methodological quality of each included study using the Physiotherapy Evidence Database (PEDro) scale for randomized controlled trials.[31] The PEDro scale consists of 11 binary (yes/no) questions and it is a widely accepted measurement tool for rating the methodological quality of randomized clinical intervention studies.[32] The tool has a maximum score of 10, as the first item is not given a point value. Any discrepancies were resolved by utilizing a third reviewer (AAW) as needed. The PEDro scale of each reviewed study was evaluated and reported in Supplementary File 2.

Consensus on Exercise Reporting Template (CERT)

Two blinded reviewers (SLD, DTT) independently extracted intervention data from each included study using the CERT reporting form with guidance from the Explanation and Elaboration Statement document.[33] The CERT is a 16-item checklist developed and endorsed by an international panel of exercise experts designed to assess the quality/comprehensiveness of reporting of exercise and contains seven categories: materials, provider, delivery, location, dosage, tailoring and compliance.[34] Following data extraction, any differences between reviewers were discussed and a final score was reached via a consensus meeting, a third reviewer (AAW) was consulted when consensus could not be met initially.

All therapeutic exercises were extracted for data analysis from the included studies. The elements of each exercise were chosen to reflect the underlying pathomechanics described earlier including: single limb loading, eccentric hip strengthening, and external loading directed around multiple planes, specifically about the z-axis.

Exercise analysis attempted to determine the authors exact intention for delivering a specific exercise as accurately as possible based on provided exercise descriptions, corresponding figures, and terminology. Three reviewers (SLD, AAW, DTT) with a combined 68 years of clinical experience initially analyzed the exercises, and exercises that needed a fourth reviewer (CMB), with 20 years of clinical experience, facilitated a final decision. The exercises were categorized utilizing the following elements and the *a priori* definitions that were used to categorize each element:

1. *Multiplanar & Triplanar*

The exercise must include primary movement within two or more of the three cardinal planes. If an exercise was scored as multiplanar, then the two or three planes were also identified in the analysis. Once identified as multiplanar, the multiplanar box was checked, and then the two or three planes were then also identified in the analysis. The final score did not include the "multiplanar" box, because the total number of planes included were tallied into the final score. If all three cardinal planes were included in the primary purpose of the exercise, then a score of 3, indicating a triplanar exercise, would be added to the remaining fields to be analyzed.

2. *Sagittal Plane*

The primary intent of the exercise utilized movement that occurred primarily within the sagittal plane. A supine straight leg raise is an example of isolated movement about the sagittal plane.

3. *Frontal Plane*

The primary movement of the exercise occurred within the frontal plane. An example of an isolated exercise to the frontal plane would be a sidelying straight leg raise.

4. *Transverse Plane*

The primary movement of the exercise occurred within the transverse plane. Seated external rotation is an isolated transverse plane exercise. Exercises that are more difficult to categorize, such as the “clam” were put into transverse and frontal if the author reported it as utilizing two planes of motion, if not, it was scored as transverse plane only.

5. *Z-axis Rotation*

The exercise needed to deliver a rotary perturbation that would induce an internal rotation of the femur about the longitudinal z-axis of the body as illustrated in Figure 1. The hip and knee must be in an extended position as if the body is in a upright weight bearing alignment. Hip external rotation in a single leg stance, is an example of an isolated z-axis rotation exercise.

6. *Bilateral Weight Bearing*

The primary movement of the exercise had both lower extremities contacting the ground in a long axis position where the hip was in a position of extension with the acetabulum over the femur in an upright bipedal position. Quadruped exercises were not considered bilateral weight-bearing for this reason. A forward lunge was considered to be a bilateral weight bearing exercise because both feet were on the ground during the intentional phase of the exercise.

7. *Single Limb Stance*

The exercise was performed on one lower extremity that was full weight bearing and contacting the ground. Several exercises were delivered in a sequential movement, whereas one foot moved in a step by step fashion. These exercises were scored as having both phases of stance. An exercise such as a side-stepping monster walk, was scored as having both bilateral and unilateral weightbearing. A single leg squat was scored as a single limb stance exercise.

8. *Eccentric Emphasis of the Hip*

The authors of this review acknowledge that most any exercise or movement has both a concentric and eccentric phase. The intent of the exercise being analyzed needed to explicitly state that the exercise was to be performed in a deceleratory manner or other language that made it clear that the goal was to accentuate or focus on the eccentric portion of the exercise. Exercises with a commonly accepted clinical focus to be eccentric, such as lateral step downs, were scored as having an eccentric focus at the hip. This analysis targets the deceleratory responsibility of the hip, specifically femoral internal rotation of the lower extremity. The analysis is attempting to identify if there was an emphasis placed on the eccentric control of the hip external rotators. Although, the muscle group that was targeted with the eccentric focus of the intervention was also noted during analysis (e.g. quadriceps, gluteus medius/maximus, external rotators of the hip).

As each exercise was analyzed it was determined how many of the above elements were accounted for within each individual exercise. Each exercise was scored out of 6 total possible points. The multiplanar column was not added into the final score for each individual exercise, because each individual plane was accounted for in the total score. Similarly, if an exercise was either bilateral or unilateral, only a score of 1 was given for being a weight bearing exercise.

## 3. Results

The initial search captured potentially relevant papers, and after removal of duplicates 2506 articles remained to be screened. After screening based on title and abstract, 2396 articles were excluded. The remaining 110 full text articles were obtained and reviewed by two authors (SLD

& AAW). Ninety-one were excluded after review of the full text, leaving 19 studies fulfilling the eligibility criteria.

Physiotherapy Evidence Database (PEDro) Scale:

The scores on the PEDro scale for the 19 included RCTs ranged from three to ten, out of a possible ten points. The most common limitation noted was the lack of blinding in the studies of both subjects and therapists. The overall average score for the included studies was 6.2 indicating a level of moderate to high quality for the included RCTs.[2,35]

Consensus on Exercise Reporting Template (CERT):

The CERT reporting form results (Supplementary File 3) ranged from 0 to 16 (19 total possible points) with an average score of 8.0. Most shortcomings concerned item 2 (qualification of exercise instructor), item 6 (motivation strategies), item 14b (how exercises are individualized), and item 16a (assessment of fidelity). For calculation of the completeness of the exercise descriptions, a single score was calculated for CERT for each study. Items 8 and 14a scored the highest; exercise description(s) and generic or individually tailored, both scoring affirmative in 17 of the 19 studies. None of the studies completed all items in the checklist.

## 4. Exercise Analysis

The total number of extracted exercises from the included studies was 178 (Table 1). Multiplanar exercises consisted of a total of 39/178, representing 21.9% of all exercises analyzed. The planes that were most frequently incorporated into the multiplanar exercises were sagittal/frontal representing 58.9% of all multiplanar exercises. Sagittal/transverse and frontal/transverse represented only 5 and 6 exercises respectively. All three planes of movement, sagittal/frontal/transverse, were included in 5 triplanar exercises. Sagittal plane exercises were the most predominantly utilized and represented a total of 120 out of 178 and accounted for 67.4% of the total exercises analyzed. The most common exercise isolated to the sagittal plane was standing hip extension in the open kinetic chain. Exercises on the frontal plane represented a total of 69 out of 178 exercises and accounted for 38.8% of all exercises analyzed. The most common exercise prescribed that was isolated to the frontal plane was open chain hip abduction. The total number of exercises in the transverse plane was 36 out of 178 representing 20.2% of the total exercises. The most commonly prescribed exercise isolated to the transverse plane was a seated external rotation exercise.

Exercises that met the a priori definition for the integration of the z-axis was the least represented component in all of the exercises. The total number of exercises that included a z-axis component was 12, representing 6.7% inclusion in all analyzed exercises. A closer look at the integration of the z-axis into the exercises found it was the lone component utilized within 3 exercises; coupled with single leg stance in 8 exercises; eccentric quadriceps for 1 exercise; and it was coupled with eccentric hip external rotators in a single leg stance for 2 exercises. These 2 exercises met 5/6 criteria. Each of the exercises were only on two planes (sagittal/transverse and frontal/transverse) and not considered to be triplanar. Almost half of the exercises analyzed (47%) only contained one of the six possible elements, exercises that contained 5/6 represented 7% and not a single exercise represented all 6 elements.

Eccentric exercises totaled 20/178, representing 11.2%. The analysis of the 20 eccentric exercises found the most represented muscle group that had an eccentric focus was of the quadriceps (12), gluteus medius (5), and hip external rotators (3). Bilateral weight bearing and single limb stance each had 43 total exercises, representing 24.2% for each category respectively. Figure 2 offers a visual representation of the results of the exercise analysis.

## 5. Discussion

The aim of this systematic review is to describe the exercise content employed within randomized controlled trials (RCTs) implementing a proximal approach to the treatment of PFP. Previous reviews have classified hip focused rehabilitation programs based on broad parameters such as open vs. closed chain and exercise dosages;[2,7,36] the next logical step was to analyze the content of individual exercises. To our knowledge this was the first review to quantify the extent to which individual exercises comprised task-specific elements (single limb stance; eccentric control of the hip; rotational z-axis control) most likely to address key pathomechanics associated with PFP. We analyzed an aggregate of 178 exercises, extracted from 19 RCTs. The number of exercises employed within each trial varied considerably, with a range of 2-21 and a median of 6 exercises per program. Most exercises reflected an isolated, reductionist approach to rehabilitation, with the majority based on sagittal plane movements with concentric loading, undertaken in a non-weight bearing position.

During walking or running, the hip musculature must quickly (50-200ms)[26] decelerate the lower limb, and plays a key role in controlling the internally rotating femur.[24,37-39] Weakness and/or delayed activation of the hip and pelvis musculature is common in PFP,[2,26,40-45] and may contribute to uncontrolled or excessive internal rotation of the femur during single limb loading. Female individuals with PFP demonstrate lower maximal muscle strength and decreased rate of force development at the hip and knee.[26] That said, it is pragmatic that PFP rehabilitation should therefore include strengthening of the proximal hip musculature, with a specific focus on neuromotor control,[27,46] speed of contractions,[26,46] and eccentrically loading the gluteals and the deep hip lateral rotators.[47] However, our review found that most strengthening exercises were limited to open chain and were concentric, with only three exercises out of 178 (< 0.0%) challenging the hip external rotators with an eccentric emphasis. We also found that strengthening was typically undertaken in either the sagittal (hip extension) or frontal plane (hip abduction), with transverse plane exercises (rotation) being the least represented (20.2%).

Although open chain, concentric strengthening represents an important stage of PFP rehabilitation, exercise interventions must be progressed to reflect the nature of the intended task.[46,48] Failing to maximally challenge PFP patients, might explain the often poor long-term prognosis associated with this condition.[14-16,46] Future interventions must incorporate more task specific loading of the hip musculature.[46] Primarily, this should include more intensive exercises designed to increase power[46], as well as, additional eccentric loading across all planes of movement.[37,49-53] Establishing triplanar control of the hip and pelvis is essential to improving both task specific neuromotor control of the proximal muscles,[27,46] and will limit contralateral pelvic drop, femoral adduction and internal rotation.[52] It is also essential that PFP rehabilitation include hip rotation, as this specifically reflects loading forces and can enhance the activity of key musculature such as the gluteus medius and minimis.[54]

Optimal rehabilitation is underpinned by progression, whereby exercises become increasingly challenging by adding new stimuli.[48] However, we found that the PFP literature is mainly comprised of basic, controlled versions of popular rehabilitation exercises in this field (eg. standing or sidelying hip abduction, seated hip external rotation), where patients focus primarily on single plane tasks or movements. By manipulating more key variables, such as speed, power and neuromotor control, PFP rehabilitation can cumulate in more complex challenges; this is more likely to improve the muscular deficits associated with PFP, lower limb alignment, reduce patellofemoral joint loads and maintain tissue homeostasis.[19,26,46] We would suggest that a key challenge for PFP is progressing rehabilitation to the point where exercise can be optimized by concomitantly providing the missing elements illustrated in the Venn diagram in Fig. 2: single limb loading, eccentric hip strengthening, external loading directed around triplanar demand, and particularly about the z-axis (Supplementary File 4).[55]

Lastly, reporting of exercise programs being utilized to treat PFP needs improvement. CERT scoring of the included studies revealed an average score of 8.0, indicating below average reporting across a number of domains, including fidelity and individualization of exercise programs. Future studies should prioritize reporting on these domains to improve homogeneity and interpretation of studies, and most importantly, to increase the success of replicating exercise programs in the clinic. Future studies may wish to employ technology for more accurate translation of exercises utilizing pictures and video formats to increase the implementation clinically. In order for research to reach clinical treatment strategies, it is relied upon that research be reported with sufficient detail to replicate the intervention. We recommended that future trials should publish details of the intervention in sufficient detail to enable clinicians to apply these in clinical practice, possibly as supplementary files.[25]

## 6. Limitations

The primary focus of this review was to determine the nature and content of hip focused rehabilitation exercises used for PFP. Our key finding was that the majority of research in this field is limited to more simplistic exercise training. This is indicative of many areas of musculoskeletal rehabilitation; whereby simplistic frameworks are applied to complex injury pathologies.[56] Whilst it is pragmatic that more clinically appropriate interventions would be associated with greater magnitudes of effect, this must be verified in future randomized studies. It is also possible that optimization of proximal exercises may create other limitations. Implementation of a more complex task-specific approach may require increased supervision, potentially making home exercises more difficult, consequently, affecting fidelity. Our results indicate that there is currently insufficient study data to consider a meta-regression, whereby key exercise variables (e.g. z axis) are included as moderator variables. Additionally, the authors acknowledge that there are likely some subjective interpretations in the categorization of existing exercise elements. Also of note are the deviations from the original PROSPERO registration.

There was a title change, two authors dropped out and one new author added, the meta-analysis was not submitted with this manuscript, and the aim was slightly altered to where the exercises that were extracted were compared to task specific movements related to the PFP injury etiology.

The authors of this review acknowledge the multidimensional nature of PFP etiology, and the complex interactions between anatomical, biomechanical, neurophysiological and biopsychosocial factors, and how these impairments intertwine with pain science.[19,42,57-64] This review only focuses on a small portion of the exercise therapy and methods that may potentially optimize a hip focused rehabilitation for PFP.

Indeed, there is evidence that incorporating exercises involving more complex task repetition with feedback is the most effective for correcting aberrant running patterns associated with PFP.[65] Although this review did not assess feedback specifically, future research may attempt to include a complex task specific exercise approach as suggested with this review and include the appropriate feedback mechanisms in future trials.

## 7. Conclusion

This review suggests that most of the rehabilitation exercises within the current evidence base may be too simplistic to address key pathomechanics associated with PFP. The inclusion of exercises targeting muscle deficits in hip muscle strength, power, and neuromotor control are crucial exercise progressions. Including these missing elements could potentially optimize PFP exercise therapy and potentially improve longer term outcomes with more complex and task specific intervention strategies. Ultimately, any newly developed exercises designed to optimize exercise therapy for PFP should be exposed to high quality prospective pragmatic and explanatory trials to determine both intervention effectiveness and efficacy.

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